National Defence / Défense nationale

Canada

COHb PREDICTION MODEL FOR PC APPLICATION

A-1

Defence and Civil
INSTITUTE OF ENVIRONMENTAL MEDICINE

INSTITUT DE MEDECINE ENVIRONNEMENTALE
pour la défense

1133 Sheppard Avenue West, PO Box 2000, North York, Ontario, Canada M3M 3B9
Tel. (416) 635-2000 Fax. (416) 635-2104

July 1996 DCIEM No. 96-TM-47

COHb PREDICTION MODEL
FOR PC APPLICATION

Peter Tikuisis

Allan A. Keefe

Defence and Civil Institute of Environmental Medicine

1133 Sheppard Avenue West, P.O. Box 2000

North York, Ontario

Canada M3M 3B9

DEPARTMENT OF NATIONAL DEFENCE - CANADA

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Exposure to carbon monoxide (CO) is endemic to the armoured vehicle environment owing to the discharge of CO from weapons firing. Given that small doses of CO can potentially impair the soldier's performance and health, it would be prudent to acquire the capability to predict CO uptake and the resultant formation of blood carboxyhemoglobin (COHb) to prevent or lessen the risk of CO toxicity. Also, given that a validated mathematical model of CO uptake already exists, a transfer of the model for PC application is the most efficient means of providing this capability.

This technical memorandum briefly describes the risk and prediction of CO uptake, and more completely describes the design philosophy behind the data inputs and presentation of results. Features include the option to input data directly or from default lists, the ability to edit inputs without restarting the program, presentations of %COHb in both tabular and graphical formats with indications of safe, cautious, and dangerous levels, the ability to store and recall exposure histories, and the ability to printout results or export them for spreadsheet application software. The convenience of a PC-formatted prediction model allows for ease of use either in the field as an operational decision aid or at the desk as an analytical tool.

INTRODUCTION

Exposure to carbon monoxide (CO) will lead to its uptake in the blood and combination with hemoglobin to form carboxyhemoglobin (COHb). Small doses are potentially lethal since CO has a binding affinity with hemoglobin that is more than 200 times that of oxygen, thus effectively reducing oxygenation in the body (Piantadosi 1996). The problem of exposure is exacerbated by the fact that human senses cannot detect CO and that the occurrence of symptoms are so non-specific as to be ignored or to cause a delay in treatment. CO exposure is endemic to the armoured vehicle environment, thereby placing at risk the soldiers' health and performance. To anticipate and help prevent exposure problems, a prediction model of COHb production has been formatted for PC application as an operational and analytical decision aid.

The enclosed 'COHb Prediction Model' is a MS Windows® based version of the mathematical CFK model (Coburn et al. 1965; Tikuisis 1996) for PC application. The prediction of an individual's COHb (in %) is based on certain physiological and environmental inputs, and a set of default values are provided to assist the user in these selections. The exposure profile and model predictions are presented in both tabular and graphical form with optional printout in hard copy. These results and data may also be saved in a file for later retrieval by either the prediction model or in a text format suitable for spreadsheet software.

The background of the graphical presentation is colour-coded to help assess the severity of the predicted COHb. Although 10% COHb has been adopted as an operational limit by the US Army (MIL-HDBK 1987; MIL-STD 1987), values of less than 15% are not considered to affect the performance of a healthy individual (Benignus 1996). And while no specific value defines the point where the individual's health is impaired, values exceeding 25% are generally considered to be dangerous (Penney 1996). These latter two limits represent the boundaries of the green (safe), yellow (caution), and red (danger) zones. A description of the installation and operating procedures of the program follows the background material.

BACKGROUND

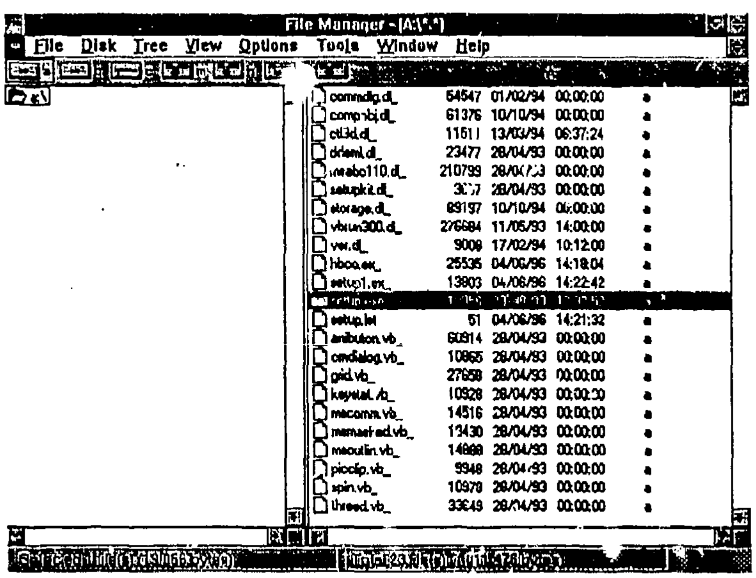
<u>Statement of Requirement:</u> Armoured vehicles are subject to CO contamination from weapons discharge (Sabiston and Severs 1994). Exposures are acute with an initial rapid rise in CO concentration followed by a slow decay lasting several minutes. Actual CO inhalation by the soldier (and consequently his/her resultant COHb) is dependent on both the soldier's proximity to the discharge of CO and his/her level of activity. These variables make it difficult

to generalize the prediction of COHb on the basis of weapons firing alone. A custom-fitted approach is required which is most efficiently realized with a PC-based program. Such a program can be broadly applied in the field for on-site predictions and at the desk for pre-planning or post analysis.

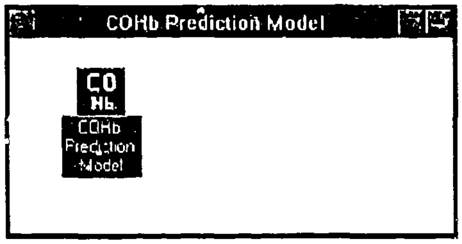
Outline of Solution: The PC program is based on the validated mathematical CFK model of CO uptake which assumes normal cardiovascular and ventilatory function (Coburn et al. 1965; Tikuisis 1996). Input variables can be adjusted to suit the individual exposure but are fixed for the duration specified (i.e., the model cannot anticipate changes in CO concentration, activity level, etc.). No restrictions, however, are placed on the number of exposures entered or their duration. For example, the release of CO from weapons firing could be simulated by a series of average CO levels and their corresponding exposure times. The following quidelines for program use describe more completely the input/output options.

PROGRAM DESCRIPTION AND USER'S GUIDE

Program Installation: The basic system requirements to run the 'COHb Prediction Model' (enclosed inside back cover) are MS Windows® 3.1 with a minimum 4MB of expanded memory. Installation begins with the insertion of the floppy disk containing the program into an appropriate drive slot (A or B) and viewing this disk using the **'File Manager'**.

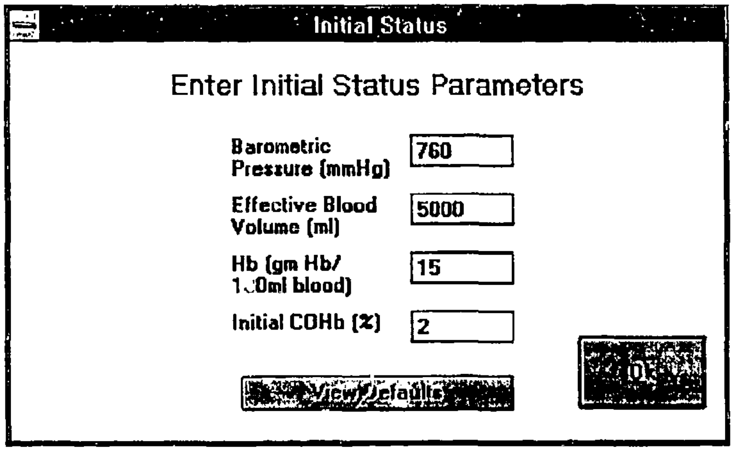


Double clicking **'setup.exe'** will install the file **'COHb.exe'** to the system and create a new group in the **'Program Manager'** containing the following COHb icon.

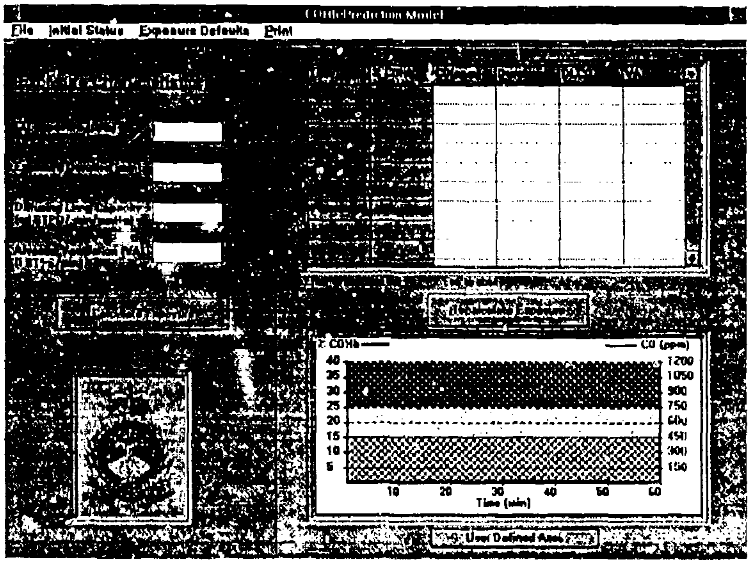


Double clicking on this icon will launch the application.

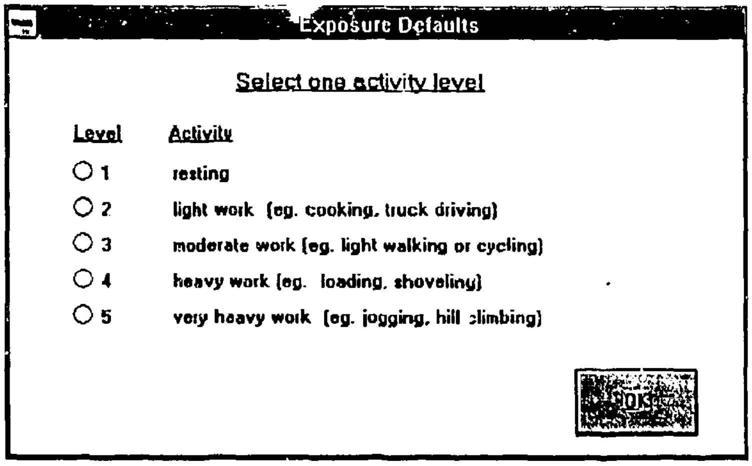
Initial Status Screen: Upon launching the program, the following input screen is displayed requesting information on barometric pressure and personal data required for the initialization of the COHb model. The default values represent normal conditions but can be overwritten. Personal data can also be selected from a secondary default list by clicking on the **'View Defaults'** button. This will present a self-explanatory list of general questions regarding the individual's height, weight, and smoking status.



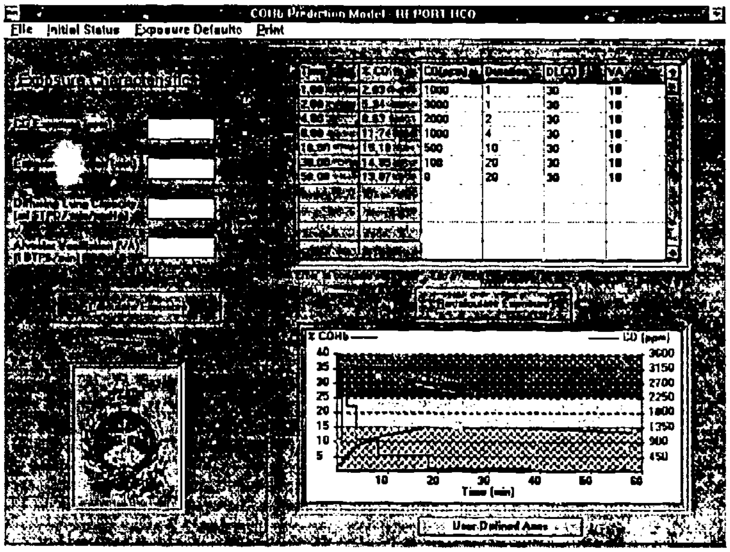
Main Screen: The main screen of the program contains the entry of exposure characteristics, calculation controls, and the presentation of the model prediction (**data grid** and **data graph**). A top-located menu bar allows further utilities such as the modification of model inputs, file I/O, and hard copy printout options.



The required input data under **'Exposure Characteristics'** are the exposure dosage of CO by concentration (parts per million) and duration (min), and the individual's ventilatory characteristics of diffusing lung capacity (DLCO in ml STPD/ mmHg/min) and alveolar ventilation (VA in L(BTPS) /min). If the latter two values are not known, default selections can be made by clicking on the '**Exposure Defaults**' option on the main menu bar.



Selecting the appropriate activity level will automatically update the main screen with representative values for DLCO and VA. When all four exposure inputs are completed, the model prediction will appear on the **data grid** (top right) and **data graph** (lower right) after clicking the '**Calculate Exposure**' button. The following figure shows an example using default initial status parameters and an exposure to CO of varying concentration and duration under moderate work conditions.



Note that the grayed-out area of the **data grid** contains the (cumulative) time and %COHb which are both calculated; the white area represents the history of exposure inputs. To change a value in this area, i) click on the desired cell, ii) enter the new value, and iii) press the keypad **'Enter'** button. Editing may be aborted at any time during i) and ii) by pressing either the keypad **'Esc'** or clicking on another cell of the grid. Once the grid has been edited, clicking on the **'Recalculate Exposure'** button initiates a recalculation of the exposure profile and an update of the graphical presentation.

The **data graph** illustrating CO concentration and the predicted %COHb is constantly updated as exposures are either added or edited. The background colours signify safe (green), cautious (yellow), and dangerous (red) levels of COHb. By default, the graph is automatically scaled and designed to display the entire profile. If desired, however, the user can define the dimensions of the axes to amplify any portion of the graph. This option is in effect until a new calculation places the data entries/results outside the previous limits.

<u>Menu Options:</u> Four bar menu items are available on the **'Main Screen'**. These are:

'File' *New* - Clears all inputs and the **data grid** and **graph**.
Open - Allows the retrieval of previously stored CO exposure profiles. By default, only files with the **'.hco'** extension may be retrieved. Once a file has been retrieved, the **data grid** and **graph** will be automatically updated and the file can be edited or appended with new data.

Save As - Allows the data exposure profile to be stored in one of two formats. The default format (**'.hco'**) stores the file in a format for later retrieval and editing using the present program. The **'.csv'** extension should be used if the file is to be exported to a spreadsheet software application such as Excel®.

Quit - Terminates the program and returns the user to Windows®.

'Initial Status' Brings forward the **'Initial Setup Screen'** containing the defaults for model initialization.

'Exposure Defaults' Brings forward a window to assist the user in selecting appropriate DLCO and VA values.

'Print' Sends a copy of the **data grid** or **graph** to the printer.

REFERENCES

Benignus VA (1996). Behavioral effects of carbon monoxide exposure: results and mechanisms. In: Carbon Monoxide. Penney DG (ed). CRC Press, Boca Raton, USA, p 211 - 238.

Coburn RF, Forster RE, Kane PB (1965). Considerations of the physiological variables that determine the blood carboxyhemoglobin concentration in man. J Clin Invest 44: 1899 - 1910.

MIL-HDBK-759A (1987). Human factors engineering design for army materiel.

MIL-STD 14472c (1987). Human engineering design criteria for military systems, equipment and facilities.

Penney DG (ed; 1996). Carbon Monoxide. CRC Press, Boca Raton, USA.

Piantadosi CA (1996). Toxicity of carbon monoxide: hemoglobin vs. histotoxic mechanisms. In: Carbon Monoxide. Penney DG (ed). CRC Press, Boca Raton, USA, p 163 - 186.

Sabiston BH, Severs Y (1994). Armoured vehicle habitability. DCIEM Report No. 94-OMD-H/OMRS.

Tikuisis P (1996). Modeling the uptake and elimination of carbon monoxide. In: Carbon Monoxide. Penney DG (ed). CRC Press, Boca Raton, USA, p 45 - 67.

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g., Establishment sponsoring a contractor's report, or tasking agency, are entered in section 12.)
DCIEM
North York, ON

2. DOCUMENT SECURITY CLASSIFICATION (overall security classification of the document including special warning terms if applicable)
UNCLAS

3. DOCUMENT TITLE (the complete document title as indicated on the title page. Its classification should be indicated be the appropriate abbreviation (S,C,R or U) in parentheses after the title.)

COHb PREDICTION MODEL FOR PC APPLICATION

4. DESCRIPTIVE NOTES (the category of the document, e.g., technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

Technical Memorandum

5. AUTHOR(S) (Last name, first name, middle initial. If military, show rank, e.g. Burns, Maj. Frank E.)

Tikuisis, Peter and Keefe, Allan A.

6. DOCUMENT DATE (month and year of publication of document)	7.a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.)	7.b. NO. OF REFS. (total cited in document)
Jul 1996	10	3

8.a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant)

8.b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)

9.a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.)

96-TM-47

9.b. OTHER DOCUMENT NO.(S) (any other numbers which may be assigned this document either by the originator or by the sponsor.)

10. DOCUMENT AVAILABILITY (any limitation on further dissemination of the document, other than those imposed by security classification)

- [√] Unlimited distribution
- [ ] Distribution limited to defence departments and defence contractors; further distribution only as approved
- [ ] Distribution limited to defence departments and Canadian defence contractors; further distribution only as approved
- [ ] Distribution limited to government departments and agencies; further distribution only as approved
- [ ] Distribution limited to defence departments; further distribution only as approved
- [ ] Other

11. ANNOUNCEMENT AVAILABILITY (any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (10.) However, where further distribution (beyond the audience specified in 10) is possible, a wider announcement audience may be selected.)

12. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)

13. ABSTRACT (a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual).

(no abstract)

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible, keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

carbon monoxide, carboxyhemoglobin, model, prediction, health risk, performance decrement